2004 GALVESTON BAY INVASIVE SPECIES RISK ASSESSMENT
INVASIVE SPECIES SUMMARY
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Common Name: European green crab (Shore Crab; Green Crab; Joe Rocker)

Latin Name: *Carcinus maenas*

Category: Aquatic Animal

Place of Origin: "The European green crab is native to the Atlantic coast of Europe and northern Africa, from Norway and the British Isles south to Mauritania (http://www.wa.gov/wdfw/fish/ans/greencrab.htm)."

Place of Introduction: "Between New Jersey and Cape Cod. Is now found in Maine, California, Oregon, and Washington. The occurrences in western North America are from a more recent invasion by the species (http://journal.conncoll.edu/~memcc/carcinus/crabmain.html)."

Date of Introduction: Early 1800s

Life History: "In the North Sea, mating takes place after the females molt from April to November, but mainly from June to October. The size of mating females generally decreases during this period. This is because most of the females that mate in June are older and have already bred at least once; the proportion of these females diminishes over time providing an opportunity for younger females to breed. Furthermore, the size of females mating for the first time decreases from July to October. Some small females molt and mate at the beginning of summer then molt and mate again after August!

In the Baltic Sea, male European green crabs molt between May and June. Males molt more often and grow larger than females, and typically mate with females smaller than themselves. When mating, the male embraces the newly molted female in order to protect her from predation or cannibalism. This type of guarding behavior may also be a means to ensure that the male is the sole partner of the female's brood. Because of their thicker shells and stronger claws, male red European green crabs compete more successfully for mates than green males. However, this advantage is gained at the cost of reduced tolerance to the conditions of intertidal life. For example, male green European green crabs are more tolerant of lower levels of salinity and oxygen (anoxia) than red males. Although egg-bearing females can be found from December to August, they are usually scarce after July. Adult crabs, particularly egg-bearing females, generally migrate to deeper water during the winter. It is hypothesized that egg-bearing females seek deeper water to take advantage of stable salinity and temperature conditions.

Most European green crabs extrude their eggs during the spring. Successful embryonic development occurs at temperatures between 11 and 25 °C. Appreciable survival of eggs to larval stages occurs at salinities between 26 and 39 ppt. In the Baltic Sea, when salinities are unfavorable (< 13 ppt), larval development may be almost completely prevented. Furthermore, it has been shown that without food, larval development can be prevented at temperatures below 6°C, even though larvae are well-adapted to a natural shortage of food in the wild.

The new larvae of European green crab, or the first stage zoea, aggregate in surface waters during the ebb tide at night when current velocities are highest. It is hypothesized that this upward swimming behavior and tidal stream transport are a means to avoid inshore stranding while enhancing offshore dispersal of the larvae. Conversely, after a period of growth and development in the open sea (about two weeks), megalopae, the last larval stage of the crab, aggregate at night in surface waters during flood. In this way, the European green crab ensures its return to coastal waters where the megalopae molt and settle out as juvenile crabs in the upper intertidal zone.

Along the central coast of Maine, mating occurs from July to October. Megalopae and early stage juvenile crabs do not settle until late August, growing to about 6 mm carapace width before winter. Renewed growth begins the following June, and juveniles grow to 13 to 25 mm carapace width by their second winter. Mature males molt by the end of July, whereas mature females molt from July to October. The European green crab reaches maturity within two to three years old, breeds up to three times, and has a minimum generation time of three years. The maximum life span of the European green crab in its native range is five years (http://www.wa.gov/wdfw/fish/ans/greencrab.htm)."

"A female green crab can produce up to 200,000 eggs per year (http://osu.orst.edu/dept/ncs/newsarch/1997/May97/crabs.htm)."

Growth/Size: "An adult European green crab is typically about 2.5 inches long, but can range up to 4 inches. The European green crabs captured in Washington have been between 19.0 mm (~0.74") to 90.0 mm (~3.5"). In the European green crabs native range the maximum size ranges up to 100 mm (~ 4") carapace width (http://www.wa.gov/wdfw/fish/ans/greencrab.htm)."

Feeding Habits/Diet: "The European green crab, *Carcinus maenas*, is a voracious predator that feeds on many types of organisms, particularly bivalve molluscs (e.g., clams, oysters, and mussels), polychaetes, and small crustaceans.

In its native range, the feeding activity of the European green crab greatly impacts populations of mussels (*Mytilus* spp.), dogwhelks (*Nucella lapillus*), and cockles (*Cerastoderma edule*). In Scotland, the crab acts as an intermediate host of the acanthocephalan worm, *Profilicollis botulus*, which causes heavy mortalities in common eiders (*Somateria mollissima*). Along the east coast of North America, the European green crab preys on quahogs (*Mercenaria mercenaria*), a hard shell clam, and has been implicated in the demise of the Atlantic soft-shell clam fisheries of the 1950s. In Bodega Bay, California, there has been a significant reduction in the populations of native clams (*Transennella* spp.) and a shore crab (*Hemigrapsus oregonensis*) since the arrival of the European green crab in 1993. Furthermore, laboratory studies show that European green crabs readily prey on Dungeness crabs (*Cancer magister*) of equal or smaller size. Dungeness crabs spend part of their juvenile life in the intertidal zone, and may therefore be at risk from European green crab predation.

The European green crab is capable of learning and can improve prey-handling skills while foraging. The crab is quicker, more dexterous, and can open shells in more ways than other species of crabs. Two color varieties exist: red and green. Red-colored European green crabs prefer larger bivalves and usually dominate green-colored European green crabs in aggressive disputes over prey. The crusher claws (the larger of the two claws) of red European green crabs exert more force, on average, than those of green European green crabs. In Denmark, the foraging activity of the European green crab is about 20 times higher in summer and fall than in winter and spring. In summer, large numbers of European green crabs move up and down the shore with the tides. European green crab usually forage during high tide, whereas females are active primarily at night, independent of the tidal phase.

Studies conducted on the European green crab in Europe indicate that when preying on bivalves, feeding rates generally decrease with increasing bivalve size and with decreasing crab size. Oysters are typically "crab-proof" at around 60 mm shell length, whereas mussels are free of predation at around 45 mm shell length. European green crabs, with a 25-75 mm carapace width, are capable of eating three oysters up to 60 mm shell length daily; a relatively low number compared to the nearly three-dozen mussels (up to 45 mm shell length) it is able to eat in the same period! Mussel populations located high in the intertidal zone tend to survive predation better than those lower in the intertidal zone (http://www.wa.gov/wdfw/fish/ans/greencrab.htm)."

Habitat: "They are found in a variety of habitats, including protected rocky shores, cobble beaches, sandflats, and tidal marshes. They can also tolerate wide ranges of salinities (4-54 ppt) and temperatures (0-33 °C) (http://www.wa.gov/wdfw/fish/ans/greencrab.htm)."

Physical Description: "Despite its name, the European green crab occasionally is not green. The dorsal (top) shell or carapace is mottled, dark brown to dark green in coloration, and has small, yellow patches. Its ventral surface (underside) color may change from green to orange and then red during the molting cycle (Figure 1). The most distinctive characteristic separating it from other Pacific Northwest crabs is the array of 5 spines on either side of the eyes on the front end of the carapace. The 3 rounded lobes (bumps) between its eyes may also be used to help identify the European green crab. The last pair of hind walking legs is relatively flat but not any more so than those on a Dungeness crab (http://www.wa.gov/wdfw/fish/ans/greencrab.htm)."

Management Recommendations / Control Strategies: include references for existing site-specific strategies

Management efforts in Washington state.

"Prevention

Prior to the arrival of the European green crab in Washington State, work was being done by various government and private entities to develop a comprehensive management strategy to address important aquatic nuisance species (ANS) issues, including the threat of a European green crab invasion. In 1998, the state completed the Aquatic Nuisance Species Management Plan called for in Section 1204 of the National Invasive Species Act of 1996. The primary objectives of the state management plan are to prevent future ANS introductions into Washington's waters through all known pathways, and develop response mechanisms for the monitoring and control of invasive species. See the WDFW Washington State Aquatic Nuisance Species Plan for more information.

As part of the effort to minimize the potential for a European green crab introduction, WDFW instituted several measures further regulating all shellfish, aquaculture and other aquatic invertebrate imports and movements within the state. One such measure was to place additional restrictions on imports from out-of-state, which included requiring one-hour chlorine dips for shellfish seed and broodstock from European green crab infested areas. Commercial shellfish growers and seafood handlers should routinely inspect their products and equipment for European green crab before making transfers to crab-free areas.

After European green crabs were found on the Washington coast, further restrictions were put in place including declaring it a deleterious species, making it illegal to transport any live specimens within the state without a special permit.

In recent years, European green crabs have become a popular animal for scientific study. As a result, it is readily available through biological supply companies. Studies using the European green crab outside its established range should be conducted in quarantine or isolation. Under no circumstances should these crabs or their progeny be released to local marine waters.

Through the subsequent work conducted by the Puget Sound/Georgia Basin International Task Force, an important recommendation provided in the ANS Management Plan is to educate Puget Sound residents about their role in preventing non-indigenous species

(NIS) from entering our marine waters. For example, people should be informed of the importance of removing marine organisms from boats and trailers before moving them.

One of the most common ways NIS, including aquatic nuisance species, can enter Puget Sound and the shared waters of Canada is through ballast water that is discharged from larger ships once they enter those waters. Ship operators should exchange ballast waters outside of the Puget Sound region to avoid introducing the European green crab or other non-native species.

Monitoring and Control

The implication of an invasion of the European green crab into Washington's bays brought quick response from the Governor and the Legislature. WDFW received emergency funds from the Governor (Fund 001-4, Appropriation Code 612-4) in the summer of 1998 in order to begin a green crab monitoring program and initiate control actions. Peripheral to this emergency funding, a Zebra Mussel and European Green Crab Task Force was established in Chapter 153 of the Washington State Laws of 1998. This task force was charged with developing recommendations for legislative consideration to prevent or control the spread of these two aquatic nuisance species. In 1999, the Washington State Legislature under ESSB 5180 directed WDFW to develop a long-term monitoring and control plan for the European green crab. WDFW has developed these monitoring and control programs as outlined below.

There are two components to the WDFW European green crab monitoring and control program: a program for the outer coast (including Willapa Bay and Grays Harbor) and a program for the Puget Sound, the San Juan Islands, and the Strait of Juan de Fuca (hereafter collectively referred to as Puget Sound). These two areas are different in terms of habitat type, ownership, and presence of European green crab; therefore, different management strategies have been developed for each area.

Biological and Chemical Control:

Biological and chemical methods to control European green crab have been proposed, however basic research for the implementation of these methods is lacking. Any alternative method to trapping would have to be carefully considered before its use.

Coastal Program

The coastal management program that has been developed to track the spread of European green crab in Washington includes both monitoring and control elements. After the first European green crab was discovered in Willapa Bay, WDFW staff, initiated a monitoring and control program, starting with a canvas of Willapa Bay and Grays Harbor by setting crayfish traps at locations where the crab was most likely to be found. Virtually all European green crabs captured in 1998 were caught in intertidal areas, dominated by introduced cordgrass (*Spartina alterniflora*) in Willapa Bay or native plants such as arrowgrass (*Triglochin maritimum*) and American threesquare (*Scirpus maritimum*) in Grays Harbor. A more detailed and rigorous annual monitoring program for the coast was designed and implemented in April 1999 with field assistance from the Puget Sound WDFW staff as well as other agencies. In 2000, our annual monitoring continued and was refined to include a dedicated local volunteer effort on the Long Beach peninsula. In 2001, the monitoring effort enlisted the help of the Makah, Quileute, and Shoalwater tribes, as well as the Columbia River Estuary Task Force (CREST) for the Columbia River to bring additional coastal areas under surveillance. To date no green crabs have been found in those areas.

The control aspect of this program seeks to reduce the number of European green crabs by trapping and removing crabs from the coastal marine ecosystem. Over 1,100 crabs have been removed from Willapa Bay and Grays Harbor over the last two and a half years. Of those, 320 have been female crabs representing a potential generation of 80 - 160 million eggs per season (research shows that a female green crab can produce 250,000 eggs twice in one season).

Puget Sound Program

In preparation for the potential spread of European green crabs, a monitoring program was launched at the end of 1998 that increases the probability for detection of a European green crab intrusion in Puget Sound, the Strait of Juan de Fuca, and the San Juan Islands. WDFW staff, volunteer groups, tribes, shellfish growers, schools, other government agencies and individual citizens are currently monitoring for the presence of the European green crab. These efforts are primarily accomplished by setting baited crayfish traps in areas that have high potential for invasion and/or have habitat characteristics that appear to be favored by European green crab in the Northwest. As part of the cooperative work that is integral to this monitoring program, WDFW has contracted with the Puget Sound Restoration Fund to train and coordinate its volunteers and the general public to monitor for the European green crab. By the end of the 2001 monitoring season, over 160 volunteers had been trained to identify and survey for the European green crab using WDFW protocols at 140 different locations throughout the Puget Sound region. In addition, WDFW staff monitor 55 sites. The development of the volunteer monitoring network is an ongoing project, and WDFW is continuously working to expand upon it every year. The larger the monitoring network and the amount of shoreline being actively examined, the greater the probability of a timely discovery of a European green crab infestation.

The control/eradication measures found to be most effective on the outer Washington coast populations will be implemented in Puget Sound in the event a European green crab infestation is discovered (http://www.wa.gov/wdfw/fish/ans/greencrab.htm)."

References (includes journals, agency/university reports, and internet links):

1. http://www.wa.gov/wdfw/fish/ans/greencrab.htm. Washington department of Fish and Wildlife. Aquatic nuisance species. European green crab (*Carcinus maenas)*

2. http://www.invasivespecies.gov/profiles/greencrab.shtml

3. http://journal.conncoll.edu/~memcc/carcinus/crabmain.html. A study of a marine invasive species: The European shore crab *Carcinus maenas*

4. http://invasions.si.edu/NIS/NIS_carcinus.htm. Smithsonian Environmental Research Center. Marine Invasions Research Lab.

Available Mapping Information:

1. Map from 1997. Map is located in the page titled "East N. America" A study of a marine invasive species: The European shore crab *Carcinus maenas*. http://journal.conncoll.edu/~memcc/carcinus/crabmain.html